Study and construction of PK Weirs in Vietnam (2004 to 2011)

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Introduction

In 2003, F.Lempérière and A.Ouamane published a paper [1] describing the concept of Piano Keys Weirs (PKW) with their two main advantages compared with the traditional labyrinth weirs:

- Possibility to place the weir on the crest of a gravity dam.
- Increase of the specific discharge.

As the PKWs seem very promising in the context of new dams in Vietnam, a program of research and development was carried out in the Ho Chi Minh University of Technology (HCMUT) with the cooperation of Hydrocoop [2]. After only some years, the results of this program, associated to those obtained in other hydraulic laboratories worldwide, allow designing PKWs that are the best solution for spillways of several new and existing dams in Vietnam and in France, with a possible large range of specific discharges [3, 4 & 6]. This paper summarizes this research and provides a short description of the PKW projects under design and construction in Vietnam.

Research and development in the HCMUT

The first stage of the research (2004-2006) with the utilization of physical models, focused on the discharge capacity versus the nappe depth for PKW of different types* (A, B & C) and a labyrinth weir [5]. The weirs had similar geometry for the comparison. The curves were established for free and submerged flows, but in a limited range of values due to the numerous parameters of the problem. The main purpose of this first research, using also the results obtained previously by other laboratories (essentially in Algeria and in France), was to define a "standard shape" for each different type of PKW and to give the approximated capacity versus the nappe depth using a simple parameter Hm. These "standard shapes" are not exactly optimal - but should be not very far from it - in order to provide a first approximation for the design. The optimization could then be performed by the designer depending on the constraints of his particular project.

**For the definition of the different types of PKW, see [7] p.20*

The second stage of the research (2007-2010) was to study the dissipation of the energy of the flow at the toe of the dam [5]. This issue is very important for the real projects as the specific discharge of a PKW can be much higher than for a Creager weir.

For this study, several physical models with a mobile bottom (sands) were used with, for the downstream face of the gravity dam, different shapes:

- a smooth inclined plane,
- a stepped inclined plane (2D) (Figure 1),
- a regular 3D inclined plane (Figure 2),
- a stepped inclined plane but with baffles regularly placed on the steps (irregular 3D) (Figure 3).

For the comparison, different weirs (Creager, PKW type B) were placed on the dam crest. The aeration of the flows and the scours at the toe of the dams were observed or measured. The purpose of this study was to contemplate the possibility of increasing the energy dissipation of the flow on the downstream face of the dam and therefore a reduction of the stilling pond sizes.

This research shows that a stepped spillway is useful with the PK weirs only for medium and high dams and only for the lower part of the dam. More sophisticated shapes (3D) do not improve significantly the dissipation of the flow energy and may present some inconveniences.

Figure 1: PKW and stepped spillway

Figure 2: Regular 3D steps

Figure 3: Steps with baffles

The third stage of the ongoing research is to define the optimal shape of PKW functioning in combination with radial gates for barrages on large rivers. This research, inspired by the Van Phong project and a recent proposal of F. Lempérière [8], will include two parts:

- A hydraulic study using physical models by the HCMUT and numerical models (Flow-3D) by EDF for comparison.
- A structural and economical study by EDF, with two cost estimates using respectively unit costs in France and unit costs in Vietnam, in order to compare the results of the optimization for a developed country and a developing country (low labor costs).

This study will also provide results for a barrage and for a gravity dam with large free and submerged overflows.

PKW under design or construction in Vietnam

The projects under construction or in design in Vietnam that feature PK Weirs include [6]:

Van Phong

The Van Phong barrage is a 475m long, 18m high reregulating structure under construction on Song Con River in Binh Dinh province in the centre of Vietnam. It will also have a 6MW powerhouse in the right abutment. In addition to its central, 172m long spillway with 10 radial gates, the barrage will also have PK Weirs of 121m and 181m lengths, respectively. The check flood event is 15 350m^3/s and the maximum combined check discharge of the PK Weirs is 8700m^3/s (the design flood is 12 450m^3/s and the combined design discharge of the PK Weir is 7520m^3/s). For floods higher than the 100 year-flood, the barrage is completely submerged.
The PK Weirs were selected as part of the project design as they can spill a significant discharge for a low nappe depth, which fits the site constraint of there being low allowable upstream water level, this combination is safer and cheaper than solutions with either all gates or flaps gates.
The Van Phong dam was studied in laboratory with 3 models at different scales and is now under construction (Figure 4).

Figure 4: Van Phong under construction

Dakmi 2

Dakmi 2 is a multipurpose scheme with irrigation and hydro features (98MW) under construction on the Dakmi River in Quang Nam province. The dam is a 38m high, 145m wide concrete gravity structure in a narrow valley with a high flood discharge.
The dam has been designed with a 31m wide, central gated spillway, and 37.5m wide PK weirs on each side of the structure. The maximum discharge capacity of the gates spillway is 3000m^3/s and combined capacities of PK Weirs is

3440m^3/s, and together they are designed to pass a 1000-year flood of almost 6500m^3/s.
The PK Weirs were chosen for the same reasons as on the Van Phong project, but the Dakmi 2 dam also has a stepped spillway for increased energy dissipation. In addition, the design avoids the need for extensive excavation on the steep left bank and also provides for good aeration of the overflow, which minimizes the size of the stilling pond (Figure 5).

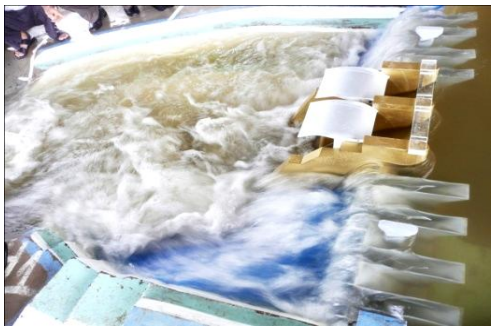

Figure 5: Test on Dakmi model

Ngan Truoi

The spillway of the Ngan Truoi irrigation dam in Ha Tinh province includes in the middle part 5 radial gates and a PKW on each side. This spillway must take into account some special constraints due to the limited capacity of the channel downstream. The inflow design flood and the design spillway flood are 5300m^3/s and 3000m^3/s, respectively. The combination of the gates and the PKWs allows some routing of the flood by the reservoir in order to reduce the peak outflow (the gates are then progressively and partially closed) and the PK weirs increase the safety of the spillway in case of blocked gates. Six stepped chutes downstream the weir are designed to reduce the energy of the flow at the channel entrance. This project is presently in study in the Hanoi hydraulic laboratory. The P K weirs confirm the results of the calculation but some issues concerning the stability of the flow at the channel entrance are not yet addressed (Figure 6).

Figure 6: Ngan Truoi global model

Vinh Son 3

Under construction in Binh Dinh province, the Vinh Son 3 hydro project features a PK Weir in its flood discharge capability. The dam is a concrete gravity dam 51m high and 317m long. The peak flood is 4000m^3/s.
The spillway, with only the PK Weir in place of the 3-gated surface spillway of the initial design, presents several advantages:
- safety in an isolated location,
- least cost of investment,
- least cost of maintenance.

An additional large diameter outlet is although foreseen for the control of the water level during the first filling and in operation and for the flushing of the reservoir.
It can be seen the good aeration of the overflow on the stepped downstream face of the dam for the maximum discharge (Figure 7). The tests confirm that the stepped spillway is useful only in the lower part of the dam and lead to some cost reduction in the reinforcement of the steps.

Figure 7: Vinh Son 3 dam model

Several other PKW spillways (Dak Rong 3, Dak Glun 2, Dak Prun 3, …) are presently in study in Vietnam but only the ones that can be visited (models or construction) during the trip following this symposium ASIA 2012 are indicated here above.

Conclusion

A combination of PK Weir and gated spillway is often the optimal solution for passing floods at dams, as indicated by the studies in Vietnam. RCC dams in high narrow valleys prone to high flood discharges could benefit from the combination of PK Weirs and stepped spillways, enabling shorter stilling basins to be built.

For long barrages on large rivers with high floods, a solution with a central gated part and two PK Weirs placed on each side, such as at Van Phong, seems very interesting as it provides a maximum of safety with the minimum costs of investment and maintenance. Some research is presently carried out in Vietnam and in France to facilitate the construction of this alternative (compared to the actual Van Phong work), in order to reduce the delay and the cost of construction of the structure (with, for example, the adoption of PKW type D or type E in place of type A, the optimization of PKW shapes, the use of precast elements, etc).

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